

“Fergusonite, an Endothermic Mineral.” By WILLIAM RAMSAY, Ph.D., LL.D., Sc.D., F.R.S., and MORRIS W. TRAVERS, B.Sc.
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The mineral fergusonite, discovered by Hartwall, occurs in felspar and mica deposits, in the same manner as most of the rare Norwegian minerals, such as euxenite, orthite, samarskite, &c. The position in which such minerals are found, embedded in masses of felspar, or encrusted with mica, leaves the question of their origin an open one. Whether they are deposited in the felspar by water, or whether they are contemporaneous with the felspar, is a matter of speculation. Fergusonite is a black lustrous mineral, not unlike obsidian in outward appearance, but of considerably higher density. Seen under the microscope, even with the highest power, there is absolutely no sign of crystalline structure, though in thin slices the substance is translucent, and transmits yellow-brown light. It is, however, macrocrystalline, occurring in quadratic sphenoids. It is quite homogeneous, and displays no sign of cavities. Like similar minerals, it contains helium, which is expelled on the application of heat.

But this mineral presents a peculiarity, which has led us to publish this note. When heated to a temperature not exceeding 500° or 600°, it suddenly becomes incandescent, and evolves much of its helium; while its density decreases.

The analysis of the mineral was kindly undertaken by Miss Emily Aston, to whom we desire to express our indebtedness. The mineral has been previously analysed by Hartwall, its discoverer, and by Weber, and, for the sake of comparison, we quote the earlier analyses* :—

Composition of Fergusonite.

	Miss Aston.	Hartwall.	Weber.
Oxides of niobium and tantalum....	40·95	47·75	48·84
Oxides of yttrium, erbium, &c.....	31·09	41·91	38·61
Oxides of cerium, &c.....	13·87	4·68	3·05
Uranium dioxide.....	3·36	—	0·95
Uranium trioxide.....	3·81	—	—
—	—	7·17	—
Titanium dioxide	4·56	—	—
ZrO ₂	—	3·02	6·93
Silica.....	1·42	—	—
Ferric oxide.....	1·55	—	—
FeO	—	0·31	1·33
Lead oxide	0·16	—	—
SnO ₂	—	1·00	0·35
Copper oxide	0·12	—	—
	100·89	99·62	99·46

* Rammelsberg's 'Mineralchemie,' p. 401.

The oxides of niobium and tantalum were converted into double fluorides of these metals with potassium fluoride; and on examination of the crystals under the microscope, they were seen to be almost entirely of one form. They were easily soluble in water, and, from previous experience with these compounds, we were able to recognise them as potassium niobium oxy-fluoride. There appears to be hardly any tantalum-fluoride present in the possible mixture. The uranium dioxide was estimated by heating the mineral with dilute sulphuric acid in a sealed tube, and titrating the dioxide with potassium permanganate. The trioxide was calculated by difference from the total uranium. The cerium metals were separated, as usual, by means of a saturated solution of potassium sulphate.

It is thus seen that fergusonite is mainly a niobate of yttrium, containing oxides of uranium, but in no great quantity.

The gases evolved by the incandescence of nearly 5 grams (4.852) of the mineral, heated in a vacuous tube, had the following composition:—

	Total gas. c.c.	Per gram of mineral. c.c.	Per cent.
Helium	5.24	1.080	75.50
Hydrogen	0.38	0.078	5.47
Carbon dioxide	1.19	0.245	17.14
Nitrogen.....	0.13	0.027	1.88
	<hr/> 6.94	<hr/> 1.430	<hr/> 99.99

The remaining mineral was mixed with hydrogen potassium sulphate, and heated to redness. More gas was evolved; oxygen, resulting from the decomposition of the sulphuric anhydride, was present in considerable quantity. The sulphur dioxide and the carbonic anhydride were removed by passing the gases through soda-lime, before it entered the pump; hence they do not appear in the analysis.

	Total gas. c.c.	Per gram of mineral. c.c.	Per cent.
Helium	3.48	0.733	60.3
Nitrogen.....	0.42	0.088	7.3
Oxygen	1.87	0.394	32.4
	<hr/> 5.77	<hr/> 1.215	<hr/> 100.0

The mineral taken weighed 4.744 grams.

The density was determined before and after heating. Great care was taken to make sure of the absence of air-bells, by warming the powdered mineral under water in a vacuum, before weighing it.

Density before heating.....	5·619
„ after „	5·375

It is thus seen that the mineral loses density on incandescence.

The amount of heat lost by this curious mineral in parting with its helium was determined. The plan of operation was to burn in oxygen a known weight of hydrogen, ascertained by measuring it, under a small platinum crucible, in a calorimeter. The rise of temperature was noted. This operation was repeated several times, so as to standardise the calorimeter. Some grams of mineral were then placed in the crucible, and the operation was repeated; the heat evolved by the incandescing mineral added itself to that from the burning hydrogen, and the rise of temperature was greater. Knowing the heat of combustion of hydrogen, a simple calculation gave the heat evolved by the exothermic change in the mineral. The actual data are as follows:—

	I.	II.	III.	IV.
Rise of temperature per gram of hydrogen	14·65°	14·68°	14·47°	14·56°
Additional rise for 6·0595 grams mineral	2·13° = 0·352° per gram			
Additional rise for 4·0830 grams mineral	1·38° = 0·338° „			
Mean rise per gram hydrogen	14·59°			
Mean rise per gram mineral	0·345°			
Heat of combustion of 1 gram hydrogen	34200 calories.			
Heat of decomposition of 1 gram mineral	809 „			

In these experiments, a correction was of course introduced for the change of temperature of the calorimeter during the experiment, due to the temperature of the surrounding air being higher or lower than that of the calorimeter.

The percentage of helium in the mineral, by weight, is 0·0194, evolved on incandescence, and on further heating, 0·0132; the total percentage is 0·0326.

Dr. Shields was so kind as to determine the specific heat of fergusonite. A Bunsen's calorimeter, in thorough working order, was used. The data are:—

Weight of mineral.....	8·789 grams.
Temperature before introducing into calorimeter..	17·3° C.
Deflection (1 mm. = 0·001053 K)	154·4 mm.
Mean specific heat between 0° and 17·3°	0·1069

Various questions are raised by the behaviour of this interesting mineral. Its evolution of heat, accompanying its parting with helium, suggest the idea that it is a true endothermic compound of helium. Had its density, as is the case with alumina, and with other oxides which rise spontaneously in temperature when heated, increased instead of decreasing, the evolution of heat might justly have been ascribed to polymerisation. But an evolution of heat, accompanied by a *fall* in density, leads to the conjecture that the loss of energy is the result of the loss of helium; and that, conversely, the formation of the compound must have been concurrent with a gain of energy. That the helium is actually in combination, and not retained in pores in the mineral, is evinced by there being no pores in which the helium might be imprisoned. Surface-absorption is equally out of the question, for the mineral is compact. The only remaining possibility is that the helium is in chemical combination. And if this is true, then the compound must be an endothermic one.

The question next arises, with what constituent of the mineral is the helium in combination? This question cannot at present be answered. All that can be said is that the amount of helium does not appear to depend on the total percentage of uranium, although minerals containing uranium usually (probably always) contain this element. Even in English pitchblende there was found a trace of helium. And in malacone, a mineral containing no uranium, a trace of helium was found; also in a specimen of meteoric iron. The presence of niobic and tantalic anhydrides, and of the yttrium group of elements, is also favourable to its presence. But the proportion between the weight of the helium and that of the other elements present makes any calculation of the atomic relations between the helium and the other elements out of the question.

There is one other substance at least which decreases in density while it evolves heat; that substance is water, in changing into ice. The effect of compressing ice is to lower its melting point, and at the same time to reduce its heat of fusion. At a sufficiently high pressure there would be a continuous transition from ice to water, no heat change taking place during the transition. Matters would be in a similar condition to those which accompany the change of a liquid into gas at the critical temperature; the smallest alteration of temperature would be enough to bring about the change. In speculating on the origin of such a remarkable compound, is it not allowable to guess that it represents a condition of our earth realised only before solidification had set in? That these minerals, containing the rare elements, represent a portion of the interior of our planet; and that under the enormous pressure obtaining at the centre, combination with helium was an exothermic event; and that such compounds, having by some unexplained accident come to the surface of the

globe, where they are no longer exposed to such pressure, they have, in consequence of the change, become endothermic? The frequency of the helium spectrum in the stars, and its presence in the sun, makes it less improbable that some such explanation may lie not far from the truth.

There are at least two other minerals, gadolinite and æschinite, which exhibit endothermic properties. But these minerals, instead of decreasing in density on ignition, increase. The following table shows the gases evolved when they are heated, their densities before and after heating, and the loss of weight which they suffer:—

	Gases evolved. c.c. per gram.				Density.		Loss of weight.
	H ₂ .	CO.	CO ₂ .	He.	Before.	After.	
Gadolinite	0·700	0·011	1·060	none	4·289	4·371	0·82
Æschinite	0·458	none	0·215	0·243	4·685	4·793	1·018

It is to be noticed that only the æschinite contains helium, and that in very small quantity.

The fact that these minerals increase in density, and that only one yields helium, places them in a different class from fergusonite. Moreover, the rise of temperature is not to be compared to that seen with fergusonite, for the glow is barely visible.

January 27, 1898.

The LORD LISTER, F.R.C.S., D.C.L., President, in the Chair.

A List of the Presents received was laid on the table, and thanks ordered for them.

The Right Hon. Sir Herbert Eustace Maxwell, a member of Her Majesty's Most Honourable Privy Council, was balloted for and elected a Fellow of the Society.

The following Papers were read:—

- I. "Mathematical Contributions to the Theory of Evolution. On the Law of Ancestral Heredity." By KARL PEARSON, M.A., F.R.S., University College, London.
- II. "On the Zoological Evidence for the former Connection of Lake Tanganyika with the Sea." By J. E. S. MOORE. Communicated by Professor LANKESTER, F.R.S.